

SECTION 23 09 00

INSTRUMENTATION AND CONTROL FOR HVAC

PART 1 - GENERAL

1.01 SECTION INCLUDES

- A. Control and interlock wiring.
- B. Motorized control dampers.
- C. Temperature control.
- D. Switches.
- E. Relays.
- F. Control panel
- G. Seven-day controls.
- H. Transformer and wiring.
- I. Airflow measuring devices.

1.02 RELATED SECTIONS

- A. Painting of mechanical equipment and components shall be as specified in Section 09 91 00 - Painting.
- B. Refer to Other Divisions for the following work:
 - 1. Power supply wiring from power source to power connection on controls and control panels. Include starters, disconnects, and required electrical devices, except where specified as furnished, or factory-installed, by the manufacturer.
 - 2. Interlock wiring between panels and switchgear provided in Division - 26 Electrical; and equipment and field-installed control devices provided herein.
- C. Provide the following electrical work as work of this Section, complying with applicable requirements of Division 26 - Electrical:
 - 1. Control wiring between field-installed controls, indicating devices, and unit control panels.

1.02 MEASUREMENT AND PAYMENT

- A. General: Separate measurement of payment will not be made for the work required under this Section. All costs in connection with the Work specified herein will be considered to be included or incidental to the Work of this Contract.

1.03 REFERENCES

- A. National Fire Protection Association (NFPA):
 - 1. NFPA 90A Standard for the Installation of Air Conditioning and Ventilating Systems
 - 2. NFPA 70 National Electrical Code
- B. National Electrical Manufacturers Association (NEMA):
 - 1. NEMA DC-3 Low-Voltage Room Thermostats
- C. Underwriters Laboratories Inc. (UL):
 - 1. UL 50 Enclosures for Electrical Equipment
- D. California Code of Regulation (CCR) Title 24

1.04 REGULATORY REQUIREMENTS

- A. Refer to Section 20 10 13 - Common Materials and Methods for Facility Services – Fire Suppression, Plumbing and HVAC, for requirements.

1.05 SUBMITTALS

- A. General: Refer to Section 01 33 00 - Submittal Procedures, and Section 01 33 23 - Shop Drawings, Product Data, Samples, for submittal requirements and procedures.
- B. Shop Drawings: Submit Shop Drawings for each electric control system, containing the following information:
 - 1. Schematic flow diagram of system showing fans, pumps, coils, dampers, valves, and control devices.
 - 2. Label each control device with setting or adjustable range of control.
 - 3. Wiring diagrams indicating all required electrical wiring. Clearly differentiate between portions of wiring that are factory-installed and portions to be field-installed.
 - 4. Logic diagrams showing sequence of events and their relationship.
 - 5. Provide details of faces of control panels, including controls, instruments, and labeling.
 - 6. Include sequence of operation.
- C. Product Data: Submit manufacturer's technical product data for each control device furnished, with certificates of compliance, indicating dimensions, capacities, performance characteristics, electrical characteristics, finishes of materials, and including installation instructions and start-up instructions.

- D. Samples: Submit sample of each type of furnished thermostat cover, in accordance with requirements of Section 01 33 23 - Shop Drawings Product Data, and Samples.
- E. Operation and Maintenance Data: Submit manufacturer's operating and maintenance instructions for all items of equipment in accordance with Section 01 78 23 - Operation and Maintenance Data.

1.06 QUALITY ASSURANCE

- A. Electrical Standards: Provide electrical products that have been tested, listed and labeled by UL and comply with NEMA standards.
- B. NEMA Compliance: Comply with NEMA standards pertaining to components and devices for electric and electronic control systems.
- C. NFPA Compliance: Comply with NFPA 90A where applicable to controls and control sequences.
- D. Manufacturer's Qualifications: Motorized dampers shall be engineered and manufactured by a company regularly engaged in the specialized manufacture of precision control dampers.

1.07 DELIVERY, STORAGE, AND HANDLING

- A. Provide factory-shipping cartons for each piece of equipment and control device. Maintain cartons through shipping, storage, and handling as required to prevent equipment damage, and to eliminate dirt and moisture from equipment. Store equipment and materials inside, protected from the weather.

1.08 SITE CONDITIONS

- A. Examine surfaces and structures where controls will be installed before the work of this Section begins. Provide surfaces and structures capable of supporting the weight of the products. Do not install controls and instruments, subject to adverse effects from vibration or conductive heat transfer, upon a wall or surface that might contribute to such adverse effects without the provision of an isolating base separating said instrument or control from the mounting surface.

PART 2 - PRODUCTS

2.01 PRODUCT REQUIREMENTS

- A. Provide electric and electronic control products in sizes and capacities indicated, consisting of dampers, thermostats, clocks, sensors, controllers, and other components as required for a complete installation.
- B. Provide manufacturer's standard control system components, designed and constructed as recommended by the manufacturer for the intended purpose and function.
- C. Provide electric and electronic control systems with functional and operational features as indicated and as specified herein.

2.02 CONTROL AND INTERLOCK WIRING

- A. Provide control and interlock internal wiring, including that required for thermostats, fans, and dampers, unless indicated otherwise. Install wiring in conduit or raceways in accordance with applicable requirements specified under Division - 26. Circuit voltage shall not exceed 120 V.
- B. Wiring shall be not smaller than AWG 14 rated at 600 V. Wiring shall conform with the California Electrical Code, NFPA 70 and to the applicable requirements of Division 26 - Electrical.

2.03 MOTORIZED CONTROL DAMPERS

- A. Provide motorized control dampers where indicated. Provide parallel blade type for two position and opposed blade type for modulation, providing proportional airflow with damper movement. For all mixing damper applications, the damper operator shall be provided with linkage to obtain a linear flow characteristic. Motorized dampers shall be engineered and manufactured by a company engaged in the regular manufacturer of precision control dampers.
- B. Individual damper sizes shall not exceed 48 inches by 48 inches. Where dampers of greater dimensions are indicated, multiple sections shall be bolted together with reinforcing strips at juncture and neoprene gasket sealer.
- C. Damper blades shall be designed so as not to sag, twist, flex, bind, or otherwise contribute to faulty operation or leakage, over the specified limit, when subjected to the system pressure. Blades shall be constructed of formed steel sheet, hot-dip galvanized after fabrication, suitable for air velocities to be encountered in the HVAC systems but not less than 16 gage. Dampers shall be rated for leakage in the full-closed position, at 50 inch-pound torque applied by the control operator. Dampers shall not leak in excess of 20 cfm per square foot at 4 inches water gage static pressure.
- D. Damper frames shall be constructed of galvanized steel roll formed into a channel with "U" cross section. Dampers shall be provided with replaceable edge seals, installed along the top, bottom, and sides of the frame and each blade.
- E. Linkage bracket and 5/16-inch diameter linkage connecting rods shall be galvanized steel. Trunnion rods shall be brass. Setscrews and mounting bolts shall be galvanized. Bearing shall be oilite or molded synthetic.
- F. Damper Operators:
 - 1. Damper operators shall be electric, with mount of sufficient quantity and torque to properly position damper against force of airflow against total damper surface. Damper operator shall provide ample closing and holding force against closed damper to ensure leak proof integrity. Modulating operation and positional operation between preset points shall be as specified under sequence of control and shall be provided with spring return for normally closed or normally open positions, as indicated. Modulating operators shall be hydraulic or oil immersed gear train type. Two position, open/close damper operators shall be of electric motor type and shall be provided where required or indicated, and shall be of sufficient capacity to operate the damper under all conditions.
 - 2. Motor operators may be reversing type for proportional control when operating in conjunction with low-voltage modulating controllers. Operators shall also be capable of

automatically operating to preset positions when controlled by snap-acting line voltage controllers. Provide for 120 V, 60 Hz service with integral 24 V transformer and auxiliary end switches as required. Operating stroke shall be adjustable from 90 degrees to 160 degrees. Running and breakaway torque shall be suitable for the application. Rotating parts shall be permanently lubricated.

- G. Damper operating speeds shall be selected or adjusted so that the operators will remain in step with the controller without hunting, regardless of load variations. Operators acting in sequence with other operators shall have adjustments of the control sequence as required by the operating characteristics of the system.

2.04 TEMPERATURE CONTROLS

- A. Thermostats shall be full proportioning or two-position type, and shall control within plus or minus 1 degree F of the temperature setting at the thermostat location as indicated. Low-voltage room thermostats shall conform with NEMA DC-3.
- B. Space thermostat shall have locking cover and shall respond to a change of not over 2 degrees F. Locking cover shall be of the key-lock type and shall be constructed so that the heating and cooling settings cannot be adjusted without removal of the locking cover. The thermostats shall have concealed set points and blank cover without thermometer, and shall have the capability of a 10-degree difference between full heating and cooling. Cover shall be heavy-duty stainless steel, satin finish. Transformer and fan relay shall be provided for the proper operation of each thermostatic control system as required. Either separate heating thermostats and separate cooling thermostats or dual element heating-cooling thermostats may be provided. Snap-acting thermostats shall be suitable for 120 V, 60 Hz service. Modulating thermostats shall be suitable for 24 V service. Thermostats shall meet requirements of the CCR, Title 24, California Energy Code.
- C. Snap-acting type heating thermostats with three or less steps of control shall be provided for electric-resistance type heaters. Thermostat shall operate in conjunction with contacts provided with heater. Heating thermostat with more than three steps of control for electric resistance-type heaters shall be for rated 24 V service, and shall modulate to position the electric motor of a step controller. The contactors of the electric heater, furnished as a part of the heater, shall make or break according to position of step-controller cam. Thermostats shall be provided with external temperature setting devices, factory set for maximum of 75 degrees F. Heating thermostats shall have an adjustable range of at least 15 degrees F below 75 degrees F.
- D. Cooling thermostats shall be designed for one or two steps of refrigeration by snap-action controlling one or two refrigeration compressors as indicated. Thermostat shall make on rise in space temperature. Thermostats shall be provided with external temperature setting devices factory set for minimum of 75 degrees F. Cooling thermostats shall have an adjustable range of at least 10 degrees F above 75 degrees F.
- E. Heating-cooling thermostats shall be provided with separate temperature sensing elements for each system. Each element shall operate switches to provide single stage control for heating and cooling. Heating and cooling circuits shall be electrically isolated from each other. Heating side scale range shall be manufacturer's standard with a factory maximum setting of 75 degrees F and an adjustable range of at least 15 degrees F below 75 degrees F. Heating circuit shall have an adjustable heater for heat anticipation. Cooling side scale range shall be manufacturer's standard with a factory minimum setting of 75 degrees F and

an adjustable range of at least 10 degrees F above 75 degrees F. Cooling circuit shall have fixed cooling anticipation heater. Thermostat shall contain, or a sub base shall be provided containing, selector switches for Heat-Off-Cool and Fan-Auto-On.

- F. Remote thermostats shall be duct-mounted or outdoor type. Set point and throttling range-adjusting mechanism for duct-mounted type shall be contained in a corrosion resistive metal case outside the duct. Outdoor compensating thermostat sensing element shall be provided with a stainless steel protective metal shield or housing, and shall be secured where indicated. Controller mechanism shall be mounted indoors where indicated. Reset ratios of the indoor-outdoor compensating thermostat shall be as indicated.
- G. Provide the following special thermostats and fan switches where indicated or required:
 1. Line-Voltage On-Off Thermostats: Provide thermostats of bi-metal actuated open contact, or bellows actuated enclosed snap-switch type, or equivalent solid-state type; UL-listed at electrical rating comparable with the application. Provide bimetal thermostats that employ heat anticipation. Equip thermostats that control electric heating loads directly, with off position on dial wired to break ungrounded conductors.
 2. Combination Thermostat and Fan Switches: Comply with requirements for line-voltage thermostats. In addition, include as integral part of each thermostat, 2-, 3-, or 4-position push-button or lever operated manual switch for control of fan in each unit with type of control as indicated. Label switches "fan on-off," "fan high-low-off," "fan high-med-low-off." Provide factory-fabricated unit, capable of being mounted on 2-gang switch box or mud ring.
 3. Low Voltage On-Off Thermostats: Comply with general requirement indicated for line-voltage thermostats. Provide thermostats of bimetal operated mercury-switch type, with either adjustable or fixed universal anticipation heater.
 4. Remote-Bulb Thermostats: Provide remote-bulb thermostats of on off or modulating type, as required by sequence of operation. Provide liquid-filled units designed to compensate for changes in ambient temperature at instrument case. Provide capillary and bulb of copper unless otherwise indicated. Equip bulbs in water lines with separate wells of same material as bulb. Support bulbs installed in air ducts securely, to prevent damage and noise from vibrations. Provide averaging bulbs where indicated or specified in operational sequence, consisting of copper tubing not less than 8 feet in length with either single or multiple-unit elements. Extend tubing to cover full width of duct or unit, and support adequately.

2.05 SWITCHES

- A. Instrumentation Switches: Provide instrumentation switches as indicated, including the following for safety and operational interlocks:
 1. Air flow switches shall be provided as indicated for monitoring the system, safety, and operational interlocks. Switches shall operate when airflow is established and break with no-flow. Extra monitoring contacts shall be provided.
 2. The switch shall be snap-acting, diaphragm-operated with pressure operating range adjustable for differential of 0.02-inch water gage to 0.08 inch water gage. Electrical

characteristics shall conform to requirements of the individual application. Switch shall have stainless steel sampling tubes and shall be duct mounted.

B. Smoke Detectors and Fire Protection Thermostats:

1. **Smoke Detectors:** Smoke detectors shall be in accordance with the requirements of Section 28 31 00 - Fire Detection and Alarm System.
2. **Fire Protection Thermostats:** Provide UL-listed fire protection thermostats where indicated. Connect thermostats, that are capable of stopping fans in event of excessive temperatures in fan control circuits. Provide thermostats with fixed or adjustable settings to operate at not less than 75 degrees F above normal maximum temperature at their location in air handling system. Comply with requirements of NFPA 90A. Provide thermostats with the following operating features:
 - a. Provide automatic reset type thermostats, with control circuit arranged to require manual reset at central control panel. Provide pilot light and reset switch on panel, clearly labeled to indicate operation of fire protection thermostat.

C. Interaction with Fire Alarm System: In addition to the fan safety cutoff, fan controls shall be interconnected with the building or station fire alarm system in a manner as specified in sequences of operation included in this Section.

2.06 RELAYS

- A. Provide electric switching relays, UL-listed, where indicated and required. Unless otherwise indicated, relays shall be installed within a control cabinet. Relays shall be of line voltage or low voltage general-purpose type unless otherwise indicated as being required of the heavy-duty type.
- B. Relay contacts shall be rated for the required amperes per pole for indicated voltage for inductive as well as resistive amperage. In addition, the contacts shall be horsepower and equivalent resistive power (kilowatt) rated.
- C. Relay coil ratings shall be in accordance with operating voltages and shall meet UL requirements for Class B coils. For operating voltage indicated coil ratings shall include voltage dropout, maximum and nominal volt-ampere inrush, maximum and nominal sealed volt-amperes, sealed wattages, and open and sealed admittance.

2.07 CONTROL PANEL

- A. Control panel shall contain remote pushbutton stations, protective devices, gages, switches, and other control devices that are not furnished integral with the controlled equipment mounted inside of control cabinet.
- B. Control cabinet shall be formed of 14 gage steel sheet. Control cabinet shall be provided for house controls, control transformer, relays, controllers, terminal strips, and similar devices where required or indicated. Cabinet shall include bezel, hinged key locking door, high/low voltage barrier, sub panel, mounting strip, rough-in ring, canopy light, tube and wire retainer, back cover plate, mounting devices, and miscellaneous attachments. Cabinet shall be factory finished with baked enamel.

- C. Instruments shall be flush mounted or back mounted and shall be completely piped and wired to a properly identified terminal strip. Piping and wiring shall be at the rear of the panel within the cabinet. Provide openings for wire and pipe into cabinet. Gages, switches, pilot lights, and pushbuttons shall be installed through door facing outside.
- D. Each control device in/on the cabinet shall be identified by a stainless steel nameplate, that is attached to or is integral with the cabinet. Lettering shall be cut into the plate to a depth of not less than 1/64 inch, and shall show a contrasting color produced by filling with enamel or lacquer, or by use of a laminated material. Painting of lettering directly on surface of the nameplate or cabinet is not permitted.
- E. The control panel shall conform to UL 50, the California Electrical Code and NFPA 70.

2.08 SEVEN-DAY CONTROLS

- A. Where required, or specified, a seven-day time switch shall be provided. Time switch shall have seven sets of adjustable trippers to set a different ON-OFF program for each 24-hour day, 10-hour spring-wound carryover with automatic electric rewind upon power restoration, and capability to automatically skip manually selected days. Operation of mechanical timer shall not affect operation of the time switch. Each time switch shall have 2-hour cam and outdoor temperature sensor to control length of warm-up periods.
- B. Where required or specified, mechanical timer shall be provided for weekend and night operation of the temperature control system. Timer operation shall not affect operation of time switch or weekend and day-night changeover controls. Activation of timer shall bypass the changeover controls and activate the day cooling or heating controls and ventilation for the area served by its thermostat and air-handling unit. Timer shall be adjustable for up to 18 hours of operation. Upon expiration of timer operation, the control system shall return to its normal mode.
- C. Where specified, control system shall have following capabilities:
 - 1. Weekend changeover for operation on Saturday and Sunday as specified for night cooling and heating.
 - 2. Day-night changeover for indexing automatically to day or night thermostats by time switch.

2.09 TRANSFORMERS AND WIRING

- A. Transformers shall be provided for electric or electronic controls when required. For temperature control system, each transformer shall be connected to an electric circuit, that serves no other equipment.
- B. Spare circuits in electric panels shall not be used for controls. Control wiring shall not be connected to lighting circuits.

2.10 AIR-FLOW MEASURING DEVICES

- A. Factory fabricated devices for direct measurement of static pressure and velocity pressure of air flow through ducting shall be duct-mounted type provided where indicated. Devices shall be provided with flanges to allow insertion in the duct system and shall be of the configuration and size approximating the duct.
- B. The permanently installed device shall operate at the design duct velocity and within the operating ranges recommended by the manufacturer. The maximum static resistance of the device to air flow shall not exceed 0.3 times the velocity head for the duct station and 0.6 times the velocity head for the fan station.
- C. The device shall not amplify nor generate sound, and shall be provided with total and static pressure sensors and air straighteners. Sensors shall be provided with pressure transmitting tubing and quick disconnect fittings for remote reading of the air flow in cfm and velocity in fpm. Tubing shall be of sufficient length for connection to a portable or stationary airflow meter at normal working level.
- D. Air measuring devices shall be tested for air flow accuracy of plus or minus 5 percent using self-verification of standard production models as determined by calibrated orifice, calibrated nozzles, or other recognized standard procedures. Test shall be carried out in an approved independent testing laboratory.
- E. Each airflow-measuring device shall have a stainless steel identification label on the unit and companion plastic tag indicating size, model, series, area, and specified airflow capacity.

PART 3 - EXECUTION**3.01 INSTALLATION**

- A. Install systems and materials in accordance with the equipment manufacturer's instructions and rough-in drawings and details. Install electrical components and use electrical products complying with applicable requirements of Division - 26 - Electrical.
- B. Install components and piping, and make all interconnections as required for a complete and operable installation.
- C. Control and interlock wiring shall be installed under applicable requirements of Division 26 - Electrical, connecting electric control equipment as well as interlocks as indicated.
- D. Location of thermostats and other exposed control sensors shall be checked and verified with plans and room details before installation. Unless otherwise indicated, thermostats shall be 60 inches above finish floor.
- E. Alarms shall be interlocked with starter switching to bypass alarm when equipment is manually disconnected.
- F. Temperature controls, relays, switches, cabinets, and other components shall be securely anchored or fastened to framing members under the surface upon that they are to be installed.

3.02 TESTING AND ADJUSTING

A. After completion of the installation, the Contractor shall, with the attendance of manufacturer's authorized representative, completely adjust all control equipment, place the system in operation, and instruct the District's operating personnel in the operation of the control system. The following shall be performed before commencing the work of Section 23 05 93 - Testing, Adjusting, Balancing for HVAC:

1. Components shall have operating pressure differential checked against range required by operating sequence, and necessary adjustments shall be made.
2. Travel of operators and linkage shall be checked and adjusted as required for automatic dampers and valves.
3. Electrical supply wiring to electric components shall be checked for proper connections and voltage. The current demand shall be measured and checked through the component against the nameplate amperes.
4. Each component shall be tested at its full operating range to ensure the required performance.
5. Automatic dampers shall be checked for binding. Those found to bind even slightly shall be made to operate freely.

3.03 START-UP

- A. Check electrical supply voltages.
- B. Check operation of components providing temperature and pressure at set points of controls.

3.04 POSTING OF CONTROL DIAGRAM

- A. Provide control diagram of each system, as prepared by the manufacturer, mounted on wall of mechanical or fan room. Provide a full-size print, framed and mounted on 1/8-inch hardboard covered with clear acrylic plastic sheet.

3.05 SYSTEM ACCEPTANCE

- A. Control manufacturer shall submit a report upon completion of the work stating that the system is complete, has been adjusted, has had all hardware and software functions verified, and is operating in accordance with the manufacturer's instructions and these Specifications. Any deviations from specified settings during system adjustment shall be specifically noted.
- B. Demonstration of complete system operation shall be made under the observation of the Engineer.

3.06 TRAINING

- A. Instruct District's personnel in the operation and maintenance of the control system in accordance with Section 01 79 00 - Demonstration and Training.

3.07 SEQUENCES OF OPERATION**A. Electric Heating Coils, Electric Cabinet Convector, Electric Baseboard Heaters, and Electric Unit Heaters:**

1. Requirements: Except as specified otherwise herein, built-in thermostats shall be provided to control terminal heating units.
2. Unit Heater Control: Provide single-temperature room thermostat to cycle fan motor and electric element to maintain constant space temperature. Provide integral residual heat sensor to continue fan operation until element temperature falls below pre-set point.
3. Electric Duct Heater Control: Provide single-temperature room thermostat to maintain constant space temperature by energizing electric strip heaters in one or more stages as indicated. Provide fail-safe operations by providing power shutoff on control signal failure.

B. Ventilating System Control:

1. HVAC Equipment Room:
 - a. Provide single-temperature room thermostat to cycle exhaust fan motor as required to maintain constant space temperature.
 - b. Exhaust fan shall start when room thermostat senses air temperature of 85 degrees F and above.
 - c. Exhaust fan shall stop when room temperature drops below 80 degrees F.
2. Battery Room for Train Control Room:
 - a. Exhaust fan shall operate continuously, and shall stop when Train Control Room supply fan stops.
 - b. Exhaust fan shall be de-energized when smoke is detected in the Train Control Room.
3. Toilet Room Exhaust: Exhaust fan shall operate continuously.

C. Heating, Ventilating, and Air Conditioning Control:

1. Train Control/Communication (TCC) Room System:
 - a. Supply fan shall operate continuously.
 - b. When outside air temperature is 55 degrees F DB and above, return air damper (RAD) shall be at minimum position and outside air damper (OAD) shall be at maximum position.
 - c. When outside air temperature is below 55 degrees F DB, RAD shall be at maximum position and OAD shall be at minimum position.

- d. When outside air temperature is higher than return air temperature, RAD shall be at maximum position and OAD shall be at minimum position.
- e. When room temperature rises above 95 degrees F in passenger station, room temperature sensor shall send signal to indicate high temperature alarm at the Station Agent's Booth and of the Train Control Center. (Only for station)
- f. Electric heating shall be activated when room thermostat senses air temperature of 60 degrees F and below.
- g. Electric heating shall be de-activated when room temperature rises above 65 degrees F.
- h. Electric heating shall be activated, regardless of room temperature, when space relative humidity exceeds 55 percent and shall be de-activated when the relative humidity drops below 50 percent.
- i. System shall be de-energized when smoke is detected in the TCC Room of a passenger station, in the supply air duct, or smoke or high air temperature in the return air duct. (Only for station)
- j. Direct expansion (DX) refrigeration system shall be controlled by room thermostat that cycles the compressors to maintain room thermostat temperature setting.

END OF SECTION 23 09 00